THE EFFECT OF WASTEWATER IRRIGATION ON STREAMFLOW AND THE HYDROLOGIC BUDGET

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REFERENCE: Proceedings of the 1989 Georgia Water Resources Conference, held May 16 and 17, 1989, at The University of Georgia. Kathryn J. Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia, 1989.

INTRODUCTION

Clayton County, Georgia, is the fourth smallest county in Georgia covering 149 square miles but has one of the fastest growing populations in the state. It is projected that the county will be the fourth most populated in the state by 1990. Located in the Piedmont physiographic region, Clayton County is dependent upon surface water for its drinking water supply. Availability of drinking water is therefore dependent upon those factors which affect the quantity and quality of surface water: precipitation, soil water and groundwater processes, and land use practices upstream from the water source.

The Clayton County Land Treatment System is a two step process consisting of secondary treatment of the county's municipal wastewater and slow rate irrigation of the effluent to forested land planted in loblolly pine (Pinus taeda L.). The system was designed for an anticipated wastewater flow of 19.6 mgd and a hydraulic loading of 2.5 in/wk over the 2,500 acre wetted area (Nutter, 1986). Operation of the system began in October, 1982 at an average rate of 9.72 mgd and has expanded to an average irrigation rate of about 14.8 mgd in 1985.

As one component of the overall water management program of the Clayton County Water Authority (CCWA), the land treatment system allows the county to "naturally recycle" its water. Wastewater is irrigated in the Pates Creek watershed which drains into the county's drinking water reservoir. The 2,500 acre irrigated site comprises 33% of the 11.9 mi^2 Pates Creek basin. An irrigation rate of 2.5 in/week (130 in/yr) is equivalent to 0.8 in/week (41.6 in/yr) on the entire watershed.

The objective of this study is to quantify the portion of flow in Pates Creek from the Clayton County land treatment system and to characterize the timing of the additional flow component. The information will be helpful in management of the Clayton County water supply system. A water budget was calculated and two components of flow were analyzed - stormflow and lowflow.

METHODS

A U.S. Geological Survey (U.S.G.S.) streamgaging station was installed on Pates Creek at Flippen Road in August 1977 and operated to September 30, 1984. Subsequently the CCWA has operated the station. Thus, five years of streamflow data (1978-1982 water years) are available for the stream before irrigation and three years after.

Five nearby basins were utilized in the study for comparison with the Pates Creek basin for selected analyses. The five watersheds chosen were the Alcovy River above Covington, Snake Creek near Whitesburg, New River near Corinth, Yellowjacket Creek near Hogansville and Little River near Buchanan. Corresponding weather stations used were Covington for the Alcovy, Carrollton for Snake Creek and Little River, and La Grange for New River and Yellowjacket Creek. A weather station was installed at the CCWA land management office in 1983. The CCWA station was used for precipitation data for Pates Creek after 1983 and published data from the Atlanta Airport Weather Service station was used before this date.

All six watersheds under study are located in the Piedmont of Georgia. Soils in this geomorphic region are relatively shallow and are underlain by crystalline igneous or metamorphic bedrock. Deep groundwater can be found in areas where it has collected in fissures in the bedrock but the dominant water drainage is lateral and influent to streams. Topography in the area is gently rolling hills and valleys created by the processes of surface water movement. All of the watersheds contain significant areas of urban development.

Water Budget

A water budget was computed for Pates Creek for the water years 1983 through 1985. Annual discharge from Pates Creek was compared with the annual discharge from each of the five comparison basins and the average of all five basins for the water years 1978 through 1984. Annual precipitation was also compared to determine variation between the six basins.

Discharge data for Pates Creek was obtained from Water Resources Data for Georgia published by the U.S.G.S. until water year 1985, when the stream-gaging station was discontinued. At that time monitoring of Pates Creek was taken over by the CCWA with the assistance of the University of Georgia School of Forest Resources. Stream data for the year 1985 was compiled with the help of facilities and staff at the Coweeta Hydrologic Experiment Station, U.S.D.A. Forest Service. Irrigation records were obtained from the CCWA. Potential evapotranspiration (PEt) for the water budget was calculated by the Thornthwaite method (Thornthwaite, 1957). It is assumed that due to irrigation actual evapotranspiration will be equivalent to potential evapotranspiration for water budget calculations.

Annual discharge data for the comparison basins was taken from the U.S.G.S. annual summaries and precipitation data was acquired from N.O.A.A. annual summaries.

Stormflow Comparison

Stormflow was separated from baseflow by a separation line of 0.05 $ft^3/sec/mi^2$ (Hewlett and Hibbert, 1967). Six hydrograph parameters were compared between stormflow hydrographs from Pates Creek and the five regional watersheds: (1) the ratio of stormflow to precipitation was approximated using data from the closest weather station in the absence of rainfall data for each watershed; (2) time to hydrograph peak discharge was used as an indication of the responsiveness of Pates Creek compared to the regional basins; (3) peak discharge rate in $ft^3/sec/mi^2$ (cfsm) was compared; (4) total stormflow volume was calculated and the time to half of the volume was computed as indication of the overall shape of the hydrograph curve; (5) the volume of flow at the peak discharge was computed and the time to half of this flow was found to compare the rising limbs of the hydrographs and; (6) time from the peak discharge to half of stormflow volume was used to compare the falling limbs of the hydrographs.

Unpublished data was obtained from the U.S.G.S., Doraville, Georgia, for use in the stormflow comparison study. Data received was in the form of hourly stage readings from analog to digital stage recorders. Stage data was converted to flow based upon rating curves obtained from the U.S.G.S.

Sixty storm events for each watershed between October 1980 and September 1984 were surveyed for possible storms of interest. Initial selection was based upon precipitation records for each station. Simple events greater than 0.75 inch were considered. Storms for which there were incomplete or bad data due to mechanical failure or rating curve problems were eliminated. Data were then run through a series of programs and further elimination occurred until 40 representative sets of data for each basin remained for the comparison.

Multivariate modelling was performed on the stormflow data from the six watersheds. A multivariate analysis of variance was performed on data using the SAS (SAS, 1985) General Linear Models (GLM) procedure. A discriminant analysis was also run on SAS to determine correlations between the six watersheds.

Low Flow Comparison

After review of results from the discriminant analysis, Little River was selected as most suitable for comparison with Pates Creek in the low flow study. Average daily flows (cfsm), for water years 1978-1983 were aligned in sequential order and repeated for the period 1983-1984. Average daily flows for Little River were subtracted from the corresponding data for Pates Creek. The sign of the difference (+ or -) was used in a Runs test to determine randomness in the daily difference in flow from the two watersheds.

The runs test is a nonparametric test commonly used in the social sciences to determine randomness in a sample. It is based on the sequence of individual observations of that sample (Siegel, 1956). In a sample containing two types of events, a run is any series of identical events preceded and followed by different types of events, or no event. The number of runs in a sample are totalled. For large samples (> 20) a z statistic is calculated which is approximately normally distributed if the sample is random.

Average daily flows for the Little River and Pates Creek watersheds for the period 1978-1984 were obtained from the U.S.G.S. annual summaries.

RESULTS AND DISCUSSION

Annual discharge and precipitation in inches from all six watersheds for the water years 1978 through 1984 were assembled. The Pates Creek percentage variation was calculated by subtracting the Pates Creek value from the regional average and dividing by the regional average.

During each of the five recorded years before irrigation, discharge from Pates Creek is below the regional average. After irrigation, discharge in Pates Creek was higher than the regional average. Precipitation at Pates Creek is below the regional average for all years except 1983. The variation of precipitation at Pates Creek from the regional average ranges from 0.6% to -9.8%. In contrast, the variation in discharge ranges from -17.9% to -33.3% before irrigation and 24.8% to 41.4% after irrigation. No statistical analyses can be made with such a short period of annual records.

The Pates Creek water balance was calculated for the three years after irrigation (water years 1983-1985) was initiated. No statistical analyses are possible but a trend is apparent. During the driest months of the year (June through October) discharge from the watershed is less than the quantity of water irrigated on the land treatment site. During the wetter, winter months (December through March), discharge is approximately double the amount irrigated.

The mean and standard deviation of the six selected stormflow hydrograph parameters were calculated. Variance between the watersheds was high for all parameters studied and the multivariate analysis of variance did not yield model capable of predicting watershed from the hydrograph parameters.

Pates Creek is one of the smaller areas monitored by the U.S.G.S. Although there were many basins with similar characteristics of soil, geology and topography, there were few of similar size. The difference in size of the comparison basins may be a key factor in the high variance between hydrographs from the six locations (Mimikou, 1984). In the discriminant analysis, the Little River, which is the smallest of the comparison basins, had the highest correlation with Pates Creek for all hydrograph parameters.

The difference between average daily flows from the Pates Creek and Little River watersheds is not random before or after irrigation. However, although the runs test does not substantiate conclusions about the direction of nonrandomness in a sample, the divergence data between mean daily discharge in Pates Creek and the Little River display distinct trends. During the period of record before irrigation, average daily flows from the Little River basin were greater than those from the Pates Creek basin 1,389 days out of 1,825, 76% of the time. In contrast, during the irrigated period, flow in Pates Creek was greater than that in the Little River 575 out of 730 days, 79% of the days studied.

SUMMARY AND CONCLUSIONS

Five years of record before irrigation and three years after irrigation were summarized into annual water budgets. Data from Pates Creek and five regional watersheds indicate a significant increase in annual discharge from Pates Creek during the first three years of wastewater irrigation. The water budget for Pates Creek during the period after irrigation indicates that this increase was predominately during the drier months of the year. Statistical analyses of the annual water budget data was not possible due to the number of years of data available.

Forty periods of stormflow data from the six watersheds were compared with multivariate statistics. All watersheds were significantly different for the parameters and stormflows studied. The variance discovered could be due to differences in hydrographs or in hydrologic characteristics of the watersheds.

Results from the low flow study show that the divergence between average daily streamflows in Pates Creek and Little River was not random before or after irrigation. There was an increase in frequency of higher daily flows in Pates Creek compared to Little River after irrigation.

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